Defence Research and Development Canada
Recherche et développement pour la défense Canada

DEFENCE R&D DÉFENSE

Assessment of the anthropometric accommodation requirements of non-pilot aircrew in the CC-150 Polaris, CP-140 Aurora, CH-149 Cormorant and CC-130 Hercules aircraft

Pierre Meunier

Defence R&D Canada
Technical Report
DRDC Toronto TR 2008-015
October 2008

Canada

Assessment of the anthropometric accommodation requirements of non-pilot aircrew in the CC-150 Polaris, CP-140 Aurora, CH-149 Cormorant and CC-130 Hercules aircraft

Pierre Meunier

Defence R&D Canada – Toronto

Technical Report
DRDC TR 2008-015
October 2008

Principal Author

Original signed by Pierre Meunier

Pierre Meunier

Approved by

Original signed by Justin Hollands

Justin Hollands, PhD

Head, Human Systems Integration Section

Approved for release by

Original signed by K.C. Wulterkens

K. C. Wulterkens, for

Chair, Document Review and Library Committee

In conducting the research described in this report, the investigators adhered to the policies and procedures set out in the Tri-Council Policy Statement: Ethical conduct for research involving humans, National Council on Ethics in Human Research, Ottawa, 1998 as issued jointly by the Canadian Institutes of Health Research, the Natural Sciences and Engineering Research Council of Canada and the Social Sciences and Humanities Research Council of Canada.

Abstract

In February 2002, the Director General Military Human Resource Policy and Planning (DGMHRPP) cancelled the Canadian Forces (CF) enrolment minimum height standard. It was concluded that “the Canadian Forces can no longer justify or defend this specific limitation (of 152 cm) on enrolment as a general standard,” although it had successfully defended it in the past. While the past arguments centered on the limited accommodation range of equipment and the liability that ill-fitting equipment had on the individual or a group (e.g., Nuclear Biological Chemical (NBC) protection), these were no longer as valid today as they were back then; newer equipment “has a wider range of sizes, adjustable seating in most vehicles, etc.” The Director General advised that “should a minimum height requirement be required, it must be occupation specific and be reflected in the occupational specifications.” Going forward, the CF requires “well supported and a defensible argument(s) that establish restriction(s) as a Bona Fide Occupational Requirement (BFOR).” This report summarizes the work that was done to establish limits of accommodation for non-pilot aircrew, specifically Flight Engineers (FE), Load Masters (LM), Airborne Electronic Sensor Operators (AESOp), and Flight Attendants. The results show that minimum heights are indeed required for these occupations.

Résumé

En février 2002, le directeur général – politiques et planification en ressources humaines militaires a aboli la norme de taille minimum des Forces Canadiennes. On a conclu que "les forces canadiennes ne peuvent plus justifier ou défendre cette limite spécifique (de 152 centimètres) comme norme générale,” bien qu'elle ait été défendue avec succès par le passé. Bien que les arguments du passé aient portés sur la gamme limitée d’accommodation de l'équipement et du danger que comporte le port d'équipement mal ajusté soit pour l'individu ou pour un groupe (par exemple protection NBC), ceux-ci ne sont plus aussi valables aujourd'hui; un plus large éventail de tailles est maintenant disponible, les sièges sont réglables dans la plupart des véhicules, etc. Le directeur général a indiqué que "si une grandeur minimum est nécessaire, elle doit être spécifique au métier et se refléter dans les caractéristiques professionnelles.” Dorénavant, les FC a besoin «d’arguments bien soutenus et défendables pour établir des exigences professionnelles justifiées.” Ce rapport résume le travail qui a été effectué pour établir des limites d’accommodation pour l'équipage aérien, en particulier les techniciens en systèmes aéronautique, arrimeurs, opérateurs de détecteurs électroniques aéroportés, et les agents de bord. Les résultats montrent qu’une stature minimale est effectivement requise pour ces professions.

This page intentionally left blank.

Executive summary

Anthropometric requirements for non-pilot aircrew in the CC-150 Polaris, CP-140 Aurora, CH-149 Cormorant and CC-130 Hercules aircraft:

Pierre Meunier; DRDC TR 2008-015; Defence R&D Canada – Toronto; April 2008.

Introduction or background: In February 2002, the Director General Military Human Resource Policy and Planning (DGMHRPP) cancelled the Canadian Forces (CF) enrolment minimum height standard. It was concluded that “the Canadian Forces can no longer justify or defend this specific limitation (of 1520 mm) on enrolment as a general standard,” although it had successfully defended it in the past. While the past arguments centered on the limited accommodation range of equipment and the liability that ill-fitting equipment had on the individual or a group (e.g., Nuclear Biological Chemical protection (NBC)), these were no longer as valid today as they were back then; newer equipment “has a wider range of sizes, adjustable seating in most vehicles, etc.” DGMHRPP advised that “should a minimum height requirement be required, it must be occupation specific and be reflected in the occupational specifications.” Going forward, the CF requires “well supported and a defensible argument(s) that establish restriction(s) as a Bona Fide Occupational Requirement (BFOR).” The object of this work was to establish limits of accommodation for non-pilot aircrew, specifically Flight Engineers (FE), Load Masters (LM), Airborne Electronic Sensor Operators (AESOp), and Flight Attendants.

Results: The results of this study show that occupational-specific anthropometric requirements are indeed required - and would still be required if the minimum height standard of 1520 mm was still in place. While some of the limitations of the tasks assessed can be alleviated through the provision of simple aids, others cannot. Most of the limitations occur at the lower end of the range, where minimum statures apply to all trades.

Upper-end limits were found for some tasks, but these had less to do with BFOR than with optimal working conditions, health and safety. For instance, although not impinging on the ability to perform the job and therefore not a BFOR, a suggested maximum for stature in the CH-149 Cormorant was provided that could be used to assign the tallest FEs to the CP-140 Aurora aircraft rather than the CH-149 Cormorant – choice permitting.

Significance: It is hoped that the present study would provide the basis for “well supported and a defensible argument(s) that establish restriction(s) as a BFOR and that the application of these limits contributes to the efficiency of operations and the health and safety of those concerned.

Future plans: A review of the information presented herein by the appropriate technical authorities will be required to establish the *Bona Fide* nature of the tasks identified as limiting, and then to obtain consensus on the required screening limits and their implementation.

Sommaire

Exigences anthropométriques pour le personnel navigant dans le CC-150 Polaris, CP-140 Aurora, CH-149 Cormorant et CC-130 Hercules

Pierre Meunier; DRDC TR 2008-015; Defence R&D Canada – Toronto; October 2008.

Introduction ou contexte : En février 2002, le directeur général – politiques et planification en ressources humaines militaires a aboli la norme de taille minimum des Forces Canadiennes. On a conclu que "les forces canadiennes ne peuvent plus justifier ou défendre cette limite spécifique (de 1520 millimètres) comme norme générale," bien qu'elle ait été défendue avec succès par le passé. Bien que les arguments du passé aient portés sur la gamme limitée d'accommodation de l'équipement et du danger que comporte le port d'équipement mal ajusté soit pour l'individu ou pour un groupe (par exemple protection NBC), ceux-ci ne sont plus aussi valables aujourd'hui; un plus large éventail de tailles est maintenant disponible, les sièges sont réglables dans la plupart des véhicules, etc. Le directeur général a indiqué que "si une grandeur minimum est nécessaire, elle doit être spécifique au métier et se refléter dans les caractéristiques professionnelles." Dorénavant, les FC ont besoin «d'arguments bien soutenus et défendables pour établir des exigences professionnelles justifiées." Le but de ce travail était d'établir des limites de d'accommodation les équipages de bord, en particulier les techniciens en systèmes aéronautique, arrimeurs, opérateurs de détecteurs électroniques aéroportés, et les agents de bord.

Résultats : Les résultats de cette étude montrent que des exigences professionnelles anthropométriques sont effectivement nécessaires - et seraient encore nécessaire si la norme de stature minimale de 1520 mm était toujours en place. Alors que certaines des limitations des tâches évaluées peuvent être palliées grâce à la fourniture d'aides simples, d'autres ne le peuvent pas. La plupart des limites surviennent à l'extrémité inférieure du spectre, et de statures minimales s'appliquent à tous les métiers.

Des limites supérieures ont été trouvées pour certaines tâches, bien qu'elles aient moins à voir avec les exigences professionnelles qu'avec des conditions optimales de travail, de santé et de sécurité. Par exemple, même si la stature maximale suggérée pour le CH-149 Cormoran n'est pas une exigence professionnelle elle pourrait être employée pour assigner un technicien plus grand à le CP-140 Aurora plutôt qu'au CH-149 Cormoran – si la situation le permet.

Importance : Il est à espérer que la présente étude puisse servir de base à des "arguments bien soutenus et défendables pour établir des exigences professionnelles justifiées" et que l'application de ces limites puisse contribuer à l'efficacité des opérations ainsi que la santé et la sécurité des personnes concernées.

Perspectives : Un examen de l'information présentée dans ce document par les autorités techniques sera nécessaire pour établir la véritable nature des tâches identifiées comme étant des

exigences professionnelles limitantes, et d'ensuite obtenir un consensus sur les limites de dépistage et sur leur mise en œuvre.

This page intentionally left blank.

Table of contents

List of figures

List of tables

Acknowledgements

The author gratefully acknowledges the help and support provided by Mr Allan Keefe.

This page intentionally left blank.

1 Introduction

1.1 Removal of minimum height requirements

In February 2002, the Director General Military Human Resource Policy and Planning (DGMHRPP) cancelled the Canadian Forces (CF) enrolment minimum height standard (Olsen, 2002). This action was taken in response to a Human Rights challenge that occurred around that time. The office of DGMHRPP concluded that "the Canadian Forces can no longer justify or defend this specific limitation (of 1520 mm) on enrolment as a general standard," although it had successfully defended it in the past. While the past arguments centered on the limited accommodation range of equipment and the liability that ill-fitting equipment had on the individual or a group (e.g., Nuclear Biological Chemical (NBC) protection), these were no longer as valid today as they were back then; newer equipment "has a wider range of sizes, adjustable seating in most vehicles, etc." DGMHRPP advised that "should a minimum height requirement be required, it must be occupation specific and be reflected in the occupational specifications." Going forward, the CF requires "well supported and a defensible argument(s) that establish restriction(s) as a Bona Fide Occupational Requirement (BFOR)," as stipulated in the Human Rights Act (Department of Justice (1985)).

1.2 Aircrew requirements

The process of establishing BFOR limits for CF pilots began in earnest in November 2001 with the funding of a study to establish the anthropometric limits for pilots. This required a systematic assessment of:

a. Reach and strength to operate all controls and displays, under the appropriate conditions;

b. Reach, strength, and clearance to achieve the full operational range of the rudders, throttles, brakes, and control stick;

c. Clearance to safely escape or eject without striking cockpit or other aircraft structures;

d. Room to allow movement for visual checks (e.g., directly behind and above the aircraft);

e. Internal vision to perform all flight tasks, including but not limited to, the ability to see all instruments, displays, cautions, and warnings;

f. External vision to perform all flight tasks, including the ability to see the landing aim point from the front cockpit over the nose of the aircraft at the worst case angle of attack approach.

A number of test subjects spanning a wide range of body shapes and sizes were selected for the purpose of testing (nearly) all cockpits in CF inventory. The performance results were quantified and expressed in accommodation prediction models using individual anthropometry as a predictor. Using the models for each essential task in each of the CF aircraft, it is possible to determine the employability of pilot candidates and to maintain a cockpit compatibility profile

throughout a pilot's career. Any rejection of a candidate is traceable to empirical data and to pass/fail criteria that were established through consultation with aircraft-specific subject matter experts (SME). In other words, the predicted inability to perform one or more of the essential piloting tasks would put the safety of individuals aboard the aircraft at unacceptably high risk or jeopardize the successful completion of the mission.

While this BFOR-based screening of pilot candidates was adopted by the CF and has been in use since April 2006, completion of the mission and the safety of the occupants is a shared responsibility of the pilots and the aircrew aboard the aircraft. Several aircraft operate with a complement of aircrew such as Flight Engineers (FE), Load Masters (LM), and Airborne Electronic Sensor Operators (AESOp). All of these occupations are physically demanding and contain interactions with equipment that is difficult to reach or tasks that could be challenging for shorter individuals. An email from Director Air Personnel Production & Development 2-4 (D Air PPD 2-4) stated: "I have canvassed the flying MOCs (Military Occupation Code) and it looks like most of them think there should be a height std" (Johnston, 2004).

1.3 Review of non-pilot aircrew requirements

In June 2006, Defence Research & Development Canada (DRDC) Toronto was tasked to study the anthropometric requirements of non-pilot aircrew and establish BFOR limits where required. The task was performed in two phases. The first phase consisted in gathering information on the types of physical tasks that aircrew need to perform. This required consultation with SMEs located in Canadian Forces Base (CFB) Trenton, CFB Shearwater and CFB Greenwood. On the basis of this consultation, a test protocol was developed that would allow the quantification of the limits for those tasks judged to be inaccessible to a portion of the male and female population. These limits can serve as selection criteria after review and approval by the SME authorities. The results of the first phase are tabulated in Annex A.

From the review of the non-pilot aircrew requirements, a subset of the tasks identified in Annex A was identified for quantitative assessment. These are summarized in Table 1 along with a description.

Table 1 Summary of tasks to be assessed quantitatively

Aircraft	Occupation	Task	Task description
CC-150 Polaris	Flight Attendant	Overhead bin - emergency kit	Flight attendants need to access and remove the survival kit from the overhead compartment in case of emergency. The kit is fairly heavy and somewhat difficult to reach for a small person.
CP-140 Aurora	Flight Engineer	Overhead reach of the bomb bay attachment mechanisms	FE need to load and unload the pannier and SKADs (Survival Kit Air Droppable) into or from internal weapons bay. When loading, the fuel tanks tend to be full and the aircraft sits low, making the pannier easier to load than with a light fuel load. Unloading is a more challenging task for shorter individuals since the aircraft sits higher by several centimetres. In that instance, even moderately tall personnel need to use some kind of boost (e.g., a milk crate, which is carried for this and other purposes) to make the job easier to do
	Flight Engineer	Take-off and landing	FE need to operate the throttles on take-off. This requires pushing the levers forward as the aircraft accelerates. The acceleration increases the difficulty of the task because the FE must resist being pushed back. The seat belt is on but is loosened to enable the reach.
	AESOp	Loading ordnance through the general purpose chute	The loading of ordnance can be done through the underbelly of the aircraft. The ordnance is pushed up through the general purpose chute and received inside the aircraft by a second crew member. This activity can be a concern if an individual is too short and cannot push the ordnance high enough to be picked from inside the aircraft.
CH-149 Cormorant	Flight Engineer	Reaching of the outboard hoist	Hoisting is one of the most demanding aspects of the FE's job. The right hand operates the hoist with the remote and the left hand pulls the load. Strength and coordination are required to bring the load in while releasing the cable using the remote control. This task is of concern for short personnel, who may not be able to reach the halo.

CH-149 Cormorant cont'd	Flight Engineer	Viewing of landing area	When landing in confined areas, FE need to scan the ground under the aircraft for obstacles that may pose a hazard to it or destabilize it. They do this by lying on their stomach over the edge of the door with their torso hanging out. They must be able to see where the wheels will contact the ground and watch for protrusions that could damage the underbelly of the aircraft. Short personnel may have limited view of the landing area as the aircraft gets close to the ground.
CC-130 Hercules	Flight Engineer	Wheel cover door lifting	FEs need to reach inside the body of the aircraft to undo the mechanism that holds the undercarriage doors open so that they can be pushed up completely to enable them to inspect the wheels etc. The two openings are rather high considering that the arms must reach down to hold and unlock the retaining pin. Even taller individuals tend to use a block to ease this task.
	Flight Engineer	Reach of bleed air valve	FE need to adjust a bleed-air valve in the cargo hold of the aircraft. It is not reachable without the help of an extension rod. Shorter individuals will find it impossible to reach and open or close the valve.
	Loadmaster	Parachute door closing	Personnel drops require the lifting of the parachute door in flight. Apart from strength, which is needed to lift the heavy door, shorter individuals have difficulty opening or closing the door.
	Loadmaster	Facility preparation and breakdown	LM need to climb up the ramp and reach for the privacy screen mechanism. A LM of average height (5 feet 9 inches or 1.76 m) has to stretch to unlock the attachment (center anchor cable support). Putting the attachment back up is even more difficult than taking it down, as it requires both hands. This task would be challenging for short individuals.
	Loadmaster	Moving in tight spaces	LM need to leave a 20 inch gap between the cargo and aircraft structure when the cargo is loaded - the gap can be as little as 14 inches at the wheel wells. Individuals need to be thin enough to circulate through these safety aisles with their clothing and equipment. Some people have been wedged-in – stuck – and had to be helped out. Not only can some people not do the job, but they could compromise the mission or be injured if this were to happen.

With the impending replacement of the CH-124 Sea King and the lack of significant problems identified in the Phase I review, it was decided to forego a detailed evaluation of that aircraft.

2 Method

2.1 General

Subjects were recruited from the pool of FE, LM, and AESOp personnel present in CFB Trenton and CFB Greenwood. Since most of the issues identified in Phase I related to reach and vision tasks, principally affecting small individuals, emphasis was given to the selection of short personnel. It should be noted that it was difficult to find anyone in these MOCs below the 50^{th} percentile in stature for males – only one was found of 30^{th} percentile. Personnel from other trades were needed to represent the lower end of the distribution. At the other end of the spectrum, the only task requiring a large individual was that of clearance when moving through the narrow cargo spaces, or safety aisles. A large individual was selected for that task.

A short description of the assessment tasks is presented below for each aircraft.

2.2 CC-150 Polaris

Participants were required to remove the emergency kit from the overhead bin with and without help from the seat arm-rest boost, as shown in Figure 1. Success or failure to remove it was noted.

Figure 1 Reaching of the emergency kit from the overhead bin

2.3 CP-140 Aurora

Participants were required to reach the attachment mechanism for the installation of the pannier and to the SKAD (Survival Kit Air Droppable) arming cable in the aircraft underbelly, as shown in Figure 2 and Figure 3. In order to enable over-reaches to contribute to the predictive regression equation, the distance between the mechanism and the wrist landmark was recorded rather than the distance to the fingertip. A similar measurement was made for reaching the arming cables, as shown in Figure 3.

Figure 2 Overhead reach of the attachement and reach measurement to wrist.

Figure 3 Measurement of reach for the SKAD arming cables.

Participants were required to reach full throttle and the fire bottle T-handles, as shown in Figure 4. The distance from the control to the wrist landmark was recorded.

Figure 4 Reach of full throttle (left) and fire bottle T-handles (right)

Participants were required to push ordnance through the general purpose chute, as shown in Figure 5. The resulting position of the ordnance was measured at the receiving end, as shown in Figure 6.

Figure 5 Ordnance (left) and the task of loading it.

Figure 6 Ordnance position measurement

2.4 CH-149 Cormorant

Participants were required to reach the inboard and outboard hoist halos with the left hand while bracing their right shoulder against the door opening. The distance between the inside of the halo and the wrist landmark was recorded, as shown in Figure 7, to the nearest 0.5 cm.

Figure 7 Reach of inboard hoist and measurement

The participants were required to lie on the floor of the cargo bay to view the area underneath the aircraft, as shown in Figure 8. Pieces of white adhesive tape were positioned plumb with the edge of the aircraft fuselage in the front, middle, and rear to serve as references for the measurement of visibility. A steel measuring tape was extended from those marks, perpendicular to the fuselage, until the participant could no longer see the tip of the tape. The maximal viewing distance was recorded in this way for the front, mid-section and rear of the aircraft.

Figure 8. Landing area monitoring from the cargo hold

2.5 CC-130 Hercules

The participants were required to reach into the wheel well to release and then reattach the door locking mechanism, with and without the help of wheel blocks as boosters. Figure 9 and Figure 10 illustrate the task and show unsuccessful and successful instances. Not shown was the reassembly of the door mechanism and the action of the foot acting on the bottom of the door to angle it so that the connecting rod hole and door holes will align well enough to accept the pin. It should be noted that this operation can only be done by feel, as the FEs cannot see the mechanism.

Figure 9 Unsuccessful reach

Figure 10 Successful reach with help of wheel block

The participants were required to actuate/reach the bleed air valve using the steel rod designed for that purpose. The missed distance – i.e., the gap between the rod and the valve - was measured using a steel measuring tape. The valve was positioned in the worst-case position, i.e., completely up. Figure 11 shows a participant a centimeter or two short of reaching the valve in its lowest position.

Figure 11 Reach for bleed air valve control (highlighted)

The participants were required to close the parachute door from the open position. Figure 12 shows the door handle position (see arrow) in relation to a tall individual. The ability of participants to reach the door handle was noted.

Figure 12 Yellow door handle next to tall subject.

The participants were required to set-up and take down the passenger comfort services (toilet). Figure 13 shows a tall individual lifting up the swivel arm in preparation for pinning to the vertical stay. The participants had to lift the swivel arm with one hand and place the locking pin (shown dangling in the picture) with the other. Since this is a two-handed operation, the participants were asked to reach up with both arms. The missed distance was measured using a steel tape measure.

Figure 13 Passenger comfort services preparation (arrow)

Pallets were placed in the cargo hold at the specified minimal distance of 35.6 cm (14 inches) from the fuselage. Participants were required to cross from the back to the front of the aircraft through that safety aisle. The minimum distance between the participant's body and the pallet was measured using a steel tape-measure.

3 Results and discussion

3.1 CFB Greenwood

3.1.1 Subjects

Participants at CFB Greenwood ranged from 1525 mm (5 feet) to 1824 mm (~6 feet) in stature, which encompasses a 3rd percentile female to a 85th percentile male based on the 1997 anthropometric survey of the land forces (Chamberland, Carrier, Forest, & Hachez, 1998). The anthropometric measurements are listed in Table 2 (see Annex B for the detailed definitions). The same individuals participated in the assessment of both the CH-149 Cormorant and the CP-140 Aurora.

Table 2 Anthropometric measurements (mm)

	Subjects					
Variable	1	2	3	4	5	6
Stature	1824	1773	1800	1525	1720	1646
Eye height	1704	1657	1688	1415	1621	1536
Acromial height	1495	1470	1485	1247	1413	1327
Overhead reach	2333	2275	2312	1905	2195	2075
Overhead reach extended	2431	2375	2403	2022	2295	2178
Functional reach	853	799	800	640	790	745
Span	1940	1804	1864	1492	1752	1670
Biacromial breadth	411	392	425	360	374	384
Bideltoid breadth	496	434	513	430	447	475
Wrist to thumb	124	117	117	100	118	114
Acromion to wrist (right)	633	613	601	507	563	535
Acromion to wrist (left)	639	605	606	516	572	532
Stature (with boots)	1860	1806	1840	1558	1752	1668
Boot height	36	33	40	33	32	22
Hand length	192	183	183	162	184	179

3.1.2 CH-149 Cormorant

Reach of hoist halo

The inboard hoist reach results were analysed using the multiple regression module of Statistica[1] 8. The anthropometric measurements were used as independent variables in a forward stepwise regression analysis. The results, shown in Table 3 and plotted in Figure 14, show that acromial height and biacromial breadth are excellent predictors of the ability to reach the inboard hoist.

[1] Statsoft Inc

The regression should be able to predict an individual's reach within 2 centimetres on average (i.e., within the standard error of the estimate), which should be good for screening purposes.

Table 3 Regression results for inboard hoist reach (Note: B denotes the regression coefficients, t denotes t-test resuts, p-level denotes probability level)

	Regression Summary for Dependent Variable: Reach_inboard hoist R= .99558385 R^2= .99118721 Adjusted R^2= .98531202 F(2,3)=168.71 p<.00083 Std.Error of estimate: 2.1731					
N=6	Beta	Std.Err. of Beta	B	Std.Err. of B	t(3)	p-level
Intercept			-232.3	15.9	-14.6	0.001
acromial height	1.105	0.097	0.1984	0.0174	11.4	0.001
biacromial breadth	-0.135	0.097	-0.1011	0.0728	-1.4	0.259

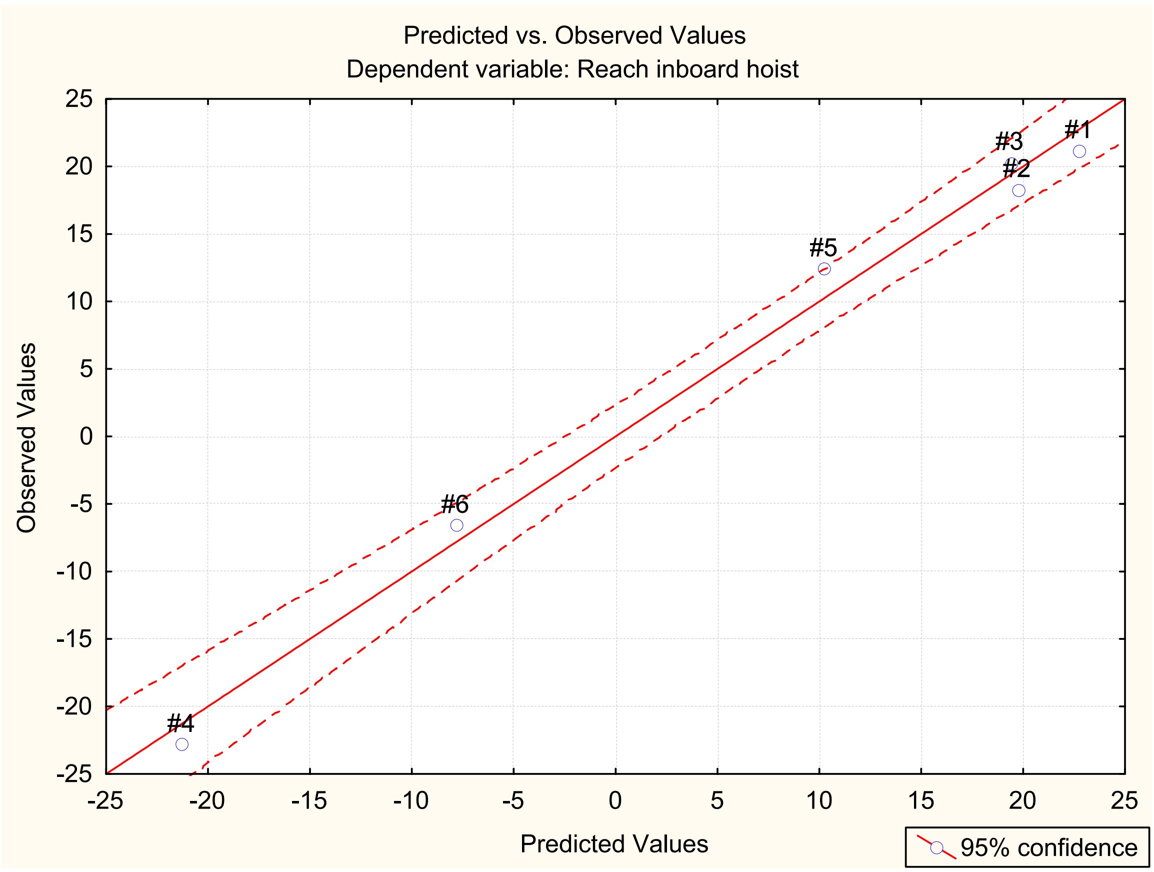


Figure 14 Predicted vs observed inboard hoist reach – negative values represent miss distance.

A less accurate model, but simpler to apply, can be obtained using stature alone. This regression, which explains 97% of the variability of the dependent variable, can predict reach performance within 3.25 cm on average. Using this model, one can infer a lower limit of 1670 mm based on Figure 15. At that stature, individuals would have a 50% chance of grasping the halo; at 1645 mm, where the dotted line intersects with 0 reach, individuals would have a 5% chance of being able to grasp the halo. Table 4 gives an indication of the percentiles these values represent, based on the 1997 anthropometric survey of the land forces, and the rejection rates that could be expected for males and females.

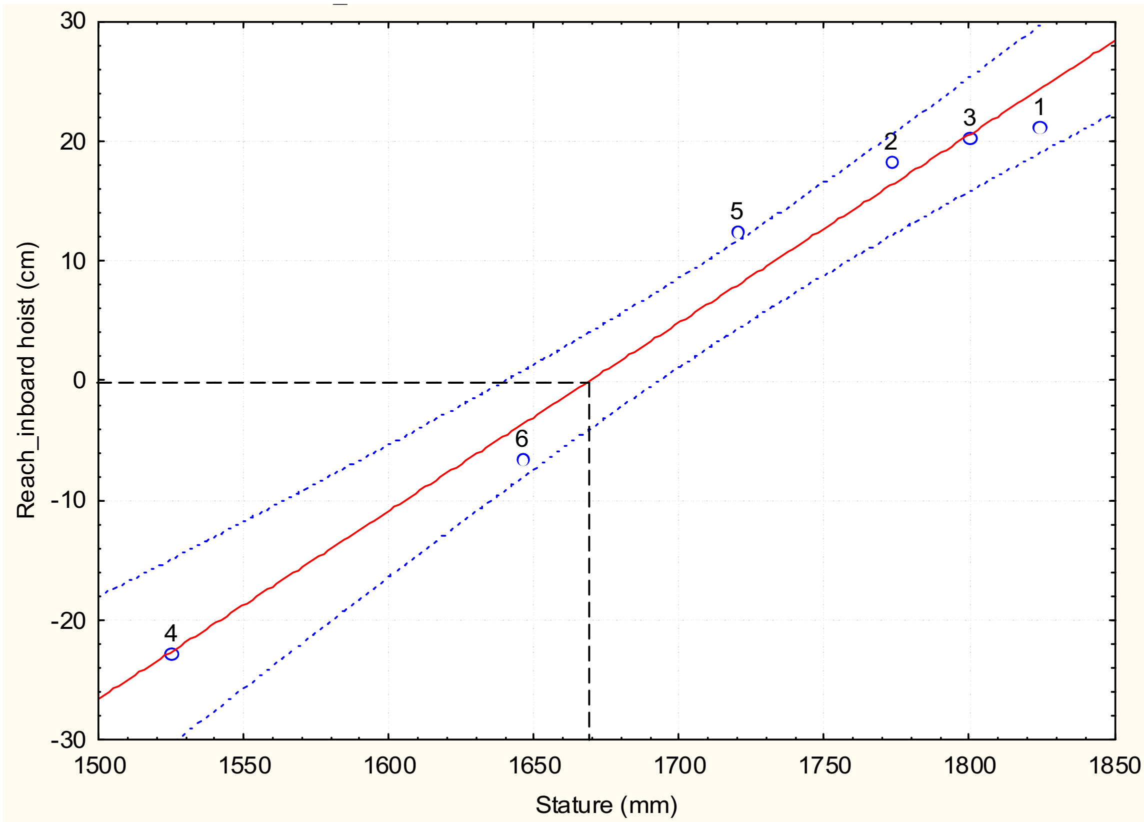


Figure 15 Inboard hoist reach vs. stature by subject – negative values represent miss distance.

Table 4 Males and female percentiles for key stature values

Stature	Percentile	
(mm)	female	male
1670	73%	10%
1645	56%	5%

The results for outboard hoist reach were somewhat more variable than those for the inboard hoist. In this case, span was the best predictor, predicting reaches within 4 cm on average. It is useful to use stature as a predictor, even though it increases the prediction error to 5 cm, as this allows a direct comparison of the inboard and outboard reaches. When this is done, an interesting situation emerges. As shown in Figure 16, both regressions cross at the critical pass/fail reach value of 0 cm. This means that anyone capable of reaching the inboard hoist should also be able to reach the outboard hoist. This is somewhat surprising in view of the fact that the outboard hoist is definitely further away from the fuselage than the inboard hoist – hence the name. However, when viewed from the operator's perspective, the two halos appear on the same arc relative to the edge of the doorway, which is where the right shoulder is placed for stability purposes. Viewed this way, the results seem plausible and point to a screening limit of 1670 mm.

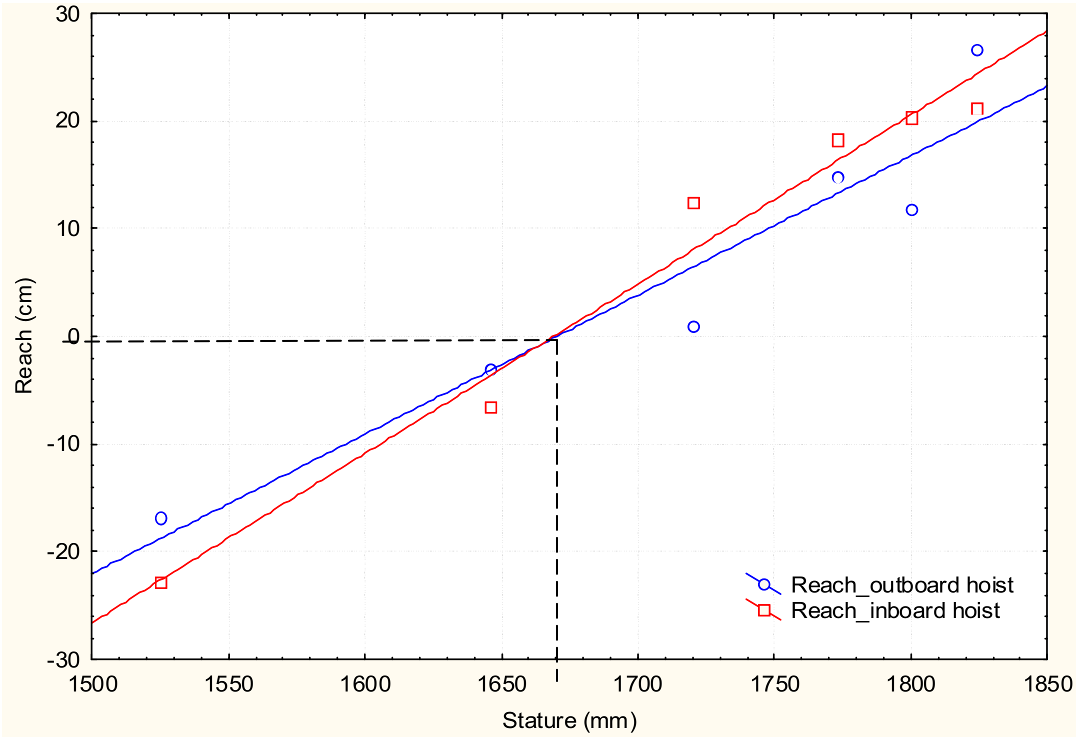


Figure 16 Comparison of outboard and inboard hoist reaches

Vision of landing area

The landing area visibility results listed in Table 5 are shown in ascending order of stature. The front, mid-section and rear measurements were not significantly different from each other ($p < 0.05$), which simply indicates that an individual can monitor the entire landing area front to rear with equal ease.

A multiple regression analysis showed that the visibility of the landing area was best predicted using stature, albeit poorly. The regression depicted in Figure 17 is one where only 50% of the variability of the dependant variable is explained by the independent variable. This points to the fact that variables other than stature are at work. Other factors such as agility, technique, and strength, could explain why anthropometry alone is not sufficient. Evidence of this was provided by Subject 2 who was able to far exceed the required viewing area. In fact, his data had to be removed from the analysis as an outlier.

Table 5 Landing area visibility results

Subject	Stature (mm)	Visibility (cm)			
		Front	Mid-section	Rear	Average
4	1525	131	134	122	129
6	1646	185	157	159	167
5	1720	215	190	205	203
2	1773	700+	700+	700+	700+
3	1800	195	201	186	194
1	1824	353	342	370	355

To be able to monitor the entire landing area, an FE must be able to view the entire width of the aircraft, which is 280 cm wide. From Figure 17, one could draw the conclusion that all by one subject met the requirement. However, the graph also represents the worst-case scenario due to the fact that visibility will increase with altitude and that the data were collected with the aircraft on the ground. Consequently, calculations were made to estimate the altitude at which each subject would just be able to see the entire landing area. The formula used, based on a vertical eye position of one meter above ground level when the aircraft is on the ground, was as follows:

$$Altitude = (Vreq/Vo - 1) \qquad \textit{Equation 1}$$

where,

Vreq = required visibility (280 cm)

Vo = visibility when the aircraft is on the ground

and where,

Vreq > Vo

Table 6, created using Equation 1, shows that even the smallest test subject would be able to monitor the full landing area down to an altitude of 1.2 meters, degrading from 100% to 46% of the area from that position to touchdown. An individual of the minimal required stature for operation of the hoists (1670 mm) would see the full landing area down to the last 0.5 m of the descent. Given the fact that anthropometry alone is not sufficient to explain visibility, that other factors such as agility may play a role, and that even the smallest of individuals can monitor the entire landing area to the last meter, this task cannot be considered limiting and should be ignored for screening purposes.

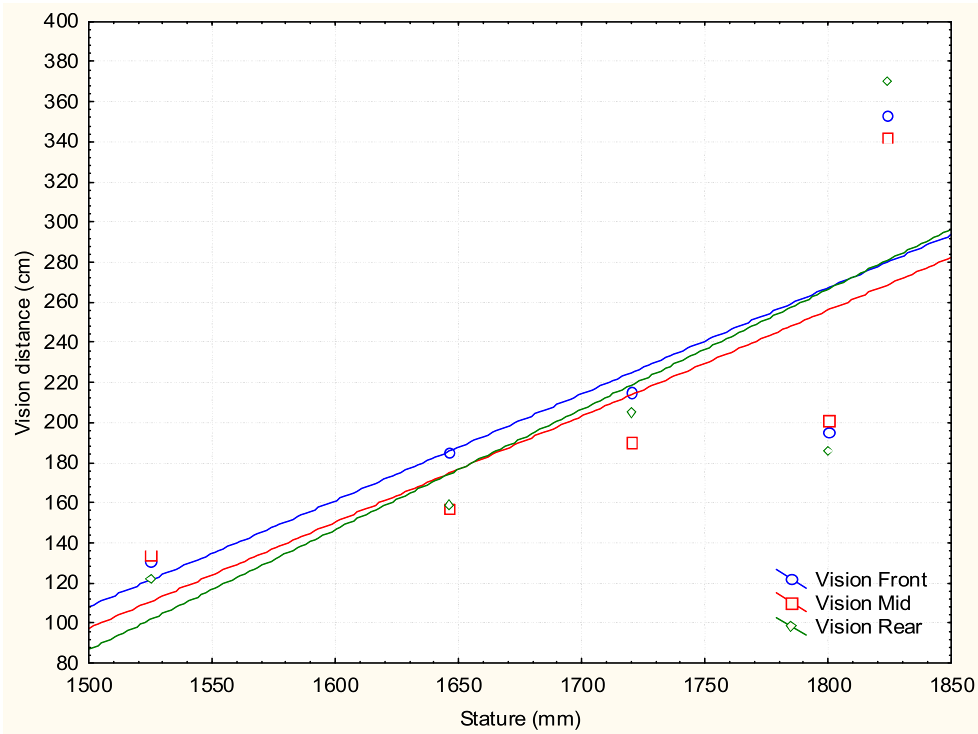


Figure 17 Vision distance from the edge of the fuselage vs. stature

Table 6 Altitude required to see the full landing area.

Subject	Stature (mm)	Altitude required for full visibility (m)
1	1824	0.0
2	1773	0.0
3	1800	0.4
4	1525	1.2
5	1720	0.4
6	1646	0.7

Other observations

It is important to note that while the results show the need for a *bona fide* minimum height requirement, anthropometry is not the only factor. Agility and experience were mentioned, but the requirement for strength is equally important. During the initial fact gathering phase of this study, it was noted that a good deal of strength and coordination are required to perform the tasks safely. For instance, loads of up to 270 kg (e.g., a combination of a SAR Tech and a casualty with wet clothing) must be pulled in with one hand while releasing the hoist cable with the other. A person

with insufficient strength would likely not be able to perform this task safely or put themselves at a higher risk of repetitive strain injury.

Similarly, when hoisting the Stokes litter, the FE needs to counter the swinging and turning action of the load at the end of the cable to ensure a controlled and safe descent and ascent from and to the cargo hold. This is also performed with one arm while the other operates the hoist remotely. When on board, the litter is then dragged-in and lifted onto the litter supports. Since patients can easily weigh over 100 kg, this activity requires strength and stamina when several patients are hoisted or several missions are completed within a short period of time.

Since hoisting is perhaps the most critical aspect of the FE's job, consideration should be given to the introduction of a suitable strength test – if one doesn't already exist – that could identify individuals requiring strength training not only to perform these difficult tasks but to perform them safely. An appropriate strength building program should be developed and administered to those requiring it.

A final observation is that the cabin height is only about 1.83 m (6 feet). This means that anyone taller than 1.77[2] m (or a 59th percentile male) will be adopting a slightly hunched posture when standing, walking about, lifting and carrying. This may be more than a nuisance in that poor posture could compound the difficulty of some of the heavy lifting and carrying tasks and thus increase the risk of musculo-skeletal injury. Ideally, FEs for the CH-149 Cormorant should be shorter than 1.77 m.

3.1.3 CP-140 Aurora

A summary of the test results is presented in Table 7. Since the reach distances were measured to the wrist, the raw results were adjusted by adding the wrist-to-thumb distance. The results of Table 7 reflect this, with the exception of ordnance, which is not a reach but a distance to the edge of the chute. The positive values represent the ability to reach (or over-reach) the target whereas the negative values represent missed distances.

The largest negative values are associated with the pannier attachment reach task, which makes it is the most difficult reach task, followed by the SKAD cable reach. No negative values were noted for the cockpit reaches, such as throttle and T-handles, as everyone was able to over-reach down to the smallest subject. The task of pushing ordnance up through the general purpose chute was also performed satisfactorily by all. The shortest subject was able to push the ordnance within 38 cm of the top edge of the chute, which made it easily accessible for any receiver.

[2] Based on a helmet thickness of 3 cm and boot thickness of 3.3 cm

Table 7 CP-140 Aurora test results

Subject	Stature (mm)	Pannier reach (cm)	SKAD reach (cm)	Ordnance distance (cm)	Throttle reach (cm)	T-handles reach (cm)
1	1824	18.9	*	7	**	**
2	1773	9.2	17.7	-8	**	**
3	1800	15.2	*	-2	**	**
4	1525	-26.0	-14.5	-38	10.0	14.0
5	1720	2.8	14.8	-12	11.8	14.8
6	1646	-10.4	17.4	-24	11.4	11.4
* over-reach not measurable ** not tested (only the shortest three individuals were tested)						

Since the pannier attachment reach is the most limiting task, a multiple regression analysis was conducted to determine the limits of accommodation. Using the anthropometrically variables listed and Table 2 as independent variables, the best predictor of performance was found to be stature. The excellence of the prediction equation is reflected in the low standard error of the regression - 1.3 cm - and a high correlation - 0.997 - as shown in Table 8.

Table 8 Regression summary for pannier reach

	Regression Summary for Dependent Variable: pannier reach (cm) R= .99775777 R^2= .99552057 Adjusted R^2= .99440071 F(1,4)=888.97 p<.00001 Std.Error of estimate: 1.2739					
	Beta	Std.Err.	B	Std.Err.	t(4)	p-level
		of Beta		of B		
Intercept			-257.132	8.693877	-29.5763	0.000008
Stature (mm)	0.997758	0.033464	0.151	0.005061	29.8156	0.000008

As shown in Figure 18, the critical stature, i.e., when a person can just reach the pins, is around 1700 mm (1703 to be exact), which represents the 88th percentile female and the 21st percentile male. These percentiles can be viewed as rejection rates for the general CF population. If practical, the use of a boost (such as a milk crate[3]) would alleviate the situation and significantly increase the pool of candidates for this job. The extra 28 cm provided by the milk crate would reduce the minimum height to about 1517 mm, which would be inclusive of the vast majority of the CF population.

[3] A plastic milk crate is commonly used for this and other purposes

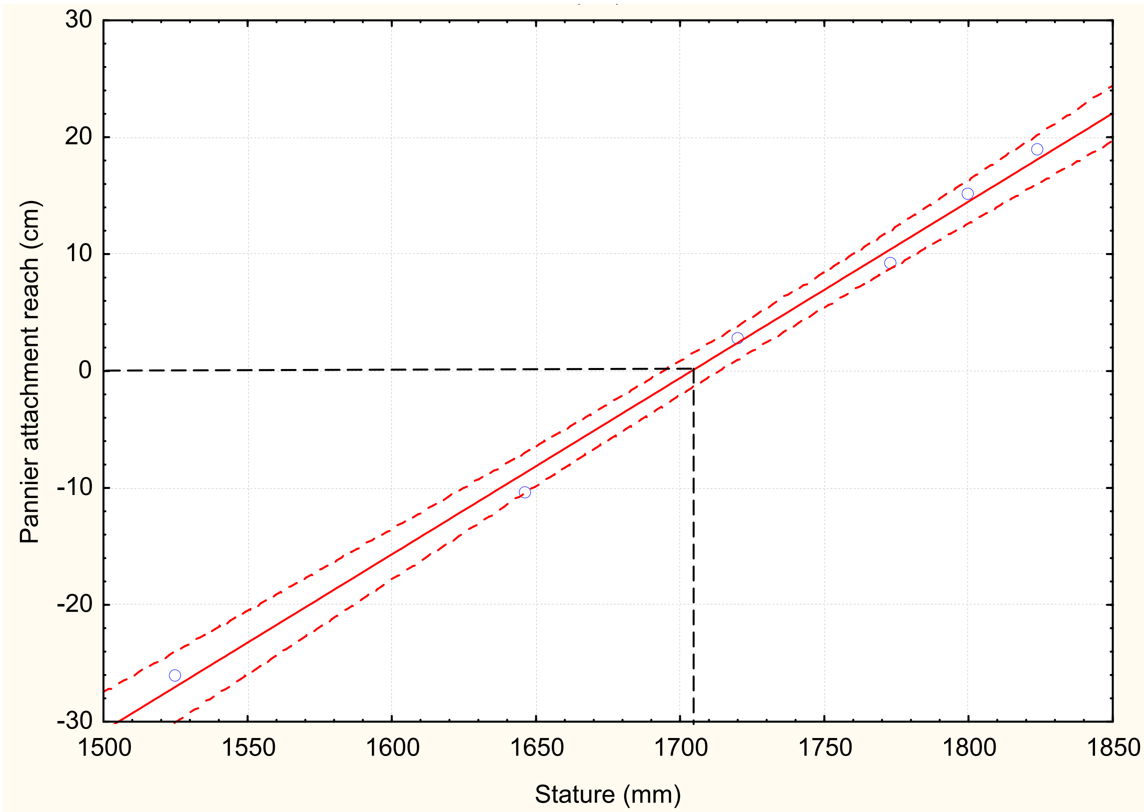


Figure 18 Pannier attachment reach as a function of stature

3.2 CFB Trenton

3.2.1 Subjects

Participants in Trenton ranged from 1506 mm (4 feet 11 inches) to 1876 mm (6 feet 2 inches) in stature, encompassing the 1st percentile female to the 97th percentile male for that dimension based on the 1997 anthropometric survey of the land forces (Chamberland, Carrier, Forest, & Hachez, 1998). The anthropometric measurements are listed in Table 9 (see Annex B for the detailed definitions). The same individuals participated in the assessment of both the CC-130 Hercules and CC-150 Polaris.

Table 9 Anthropometry of Trenton participants

Measurements (mm)	Subjects						
	1	2	3	4	5	6	7
Weight (kg)	72.7	45.5	113.6	43.2	61.4	59.1	74.0
Stature	1576	1530	1876	1506	1577	1570	1646
Eye height	1456	1433	1760	1404	1466	1470	1536
Acromial height	1290	1260	1567	1222	1281	1316	1327
Overhead reach	2020	1935	2414	1907	2042	2080	2075
Overhead reach extended	2106	2053	2508	1986	2136	2182	2178
Functional reach	690	696	850	640	682	757	745
Span	1582	1573	1925	1525	1620	1756	1670
Chest depth	292	217	292	216	258	269	262
Waist depth	277	187	331	186	201	229	248
Hip depth	272	215	326	218	240	251	266
Wrist to thumb	120	113	122	98	111	109	114
Acromion to wrist distance	518	503	635	491	521	582	535

3.2.2 CC-130 Hercules

Wheel inspection task

The task of releasing the wheel cover mechanism and re-setting it is rather difficult and requires a certain amount of practice. Most of the subjects were unfamiliar with this task and were developing strategies to complete it as the test carried on. For instance, people got better at counterbalancing the cover/door with one leg to remove the locking pin. The same technique is essential to be able to re-align the mechanism and replace the pin. The main difficulty of the task comes from not being able to see the mechanism during this operation, which means it has to be performed by feel.

Given the height of the openings relative to the ground and the difficulty of the task, it was surprising to see that even the smallest participants were able to release and re-set the mechanism using the wheel blocks as a boost. Without the wheel blocks, all were able to at least remove the pin, but three were unable to re-set the mechanism. The results, shown in Table 10 (in ascending order of stature) show that the ability to execute the task is related to stature. However, observations indicate that dexterity and practice are also important factors.

Table 10 Results of wheel cover removal versus stature.

Subject	Stature (mm)	Wheel cover - no blocks	Wheel cover - w/blocks
4	1506	fail *	pass
2	1530	fail *	pass
6	1570	pass	pass
1	1576	fail *	pass
5	1577	pass	pass
7	1646	pass	pass
3	1876	pass	pass
* Able to remove pin but not reposition it.			

Bleed-air valve reach

A multiple regression analysis found stature to be the best predictor of bleed-air valve reach, with a Pearson correlation coefficient of 0.98 and a standard error of estimate of 30 mm. Some variability was introduced by the way some of the participants grasped the tool – e.g., fully grabbing the handle or holding the bottom of the handle with two fingers – but the results were reasonably consistent in spite of that. Figure 19 shows that individuals need to be around 1770 mm in stature to be able to fully actuate the valve. This represents 99th percentile female and 60th percentile male. If this task is deemed important, this problem could be remedied by a longer extension rod. Based on the results of this study, an extra 275 mm would be required to accommodate the smallest subject and thus cover the entire population.

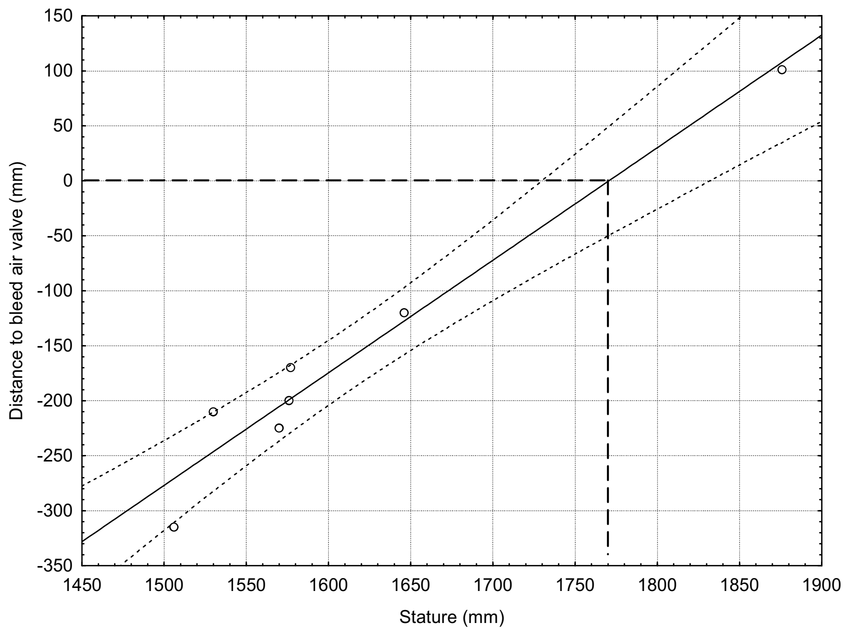


Figure 19 Bleed air valve reach versus stature.

Parachute door operation

Operation of the parachute door is a critical aspect of the LM's job, but unfortunately, a realistic assessment of this task was not possible for at least two reasons. The first one is that there is a significant aerodynamic effect acting on the door that is present in flight but that cannot be replicated on the ground. This effect makes it much more difficult to open the door, as pointed out by the SMEs, which would make a ground assessment unrepresentative of the real task. In other words, the ability to perform this task on the ground would therefore not necessarily be indicative of the ability to perform it under the real conditions. The second reason is that there is a safety element attached to this task that can make the difference between falling out of the aircraft and staying in. The criteria for a safe door opening would need to be established before a proper assessment could be done. And beyond those two concerns, there would be a need to develop a task-specific strength assessment to predict the success or failure of individuals during screening. While the initial intent was to delve into this type of biomechanical assessment, it was soon realised that a separate study would be required. It was decided to limit this study to its original scope, which was to establish the anthropometric limits of accommodation. Therefore, the only aspect of this task that would be assessed is the ability to reach the door handle when the door was up.

The results of the parachute door reach are shown in Table 11. The data are tabulated in ascending order of stature to show the link between that variable and the ability to reach. The results indicate that this task is not too challenging from an anthropometric perspective. Individuals as small as 1530 mm in stature, or 3rd percentile female, are able to do the kinematics of the task. However, weak individuals would not be able to open the door.

While the present study did not address all aspects of this task, it indicated that the door operation is less a question of anthropometry than it is of strength. Since this is perhaps the most critical aspect of the LM's job, consideration should be given to the introduction of a suitable strength test – if one doesn't already exist – that could at least identify those requiring strength training to be effective and safe.

Table 11 Stature versus Parachute door reach

Subject	Stature	Parachute door reach (closing)
4	1506	fail
2	1530	pass
6	1570	pass
1	1576	pass
5	1577	pass
7	1646	pass
3	1876	pass

Passenger comfort services set-up

Setting up of the passenger comfort services is an awkward task and proved to be a challenging one for short individuals. As shown in Figure 20, the stature required to perform this task successfully is about 1700 mm. This value represents the 88^{th} percentile female and the 21^{st} percentile male. These percentiles can be viewed as rejection rates for the general CF population. Unlike in the case of the CP-140 Aurora, where the task is performed on the ground and a milk crate or small ladder can be used, set-up of the passenger comfort services is performed in flight and from an angled platform. Unless an aid of some sort can be provided, the recommended minimum stature should be established at 1700 mm.

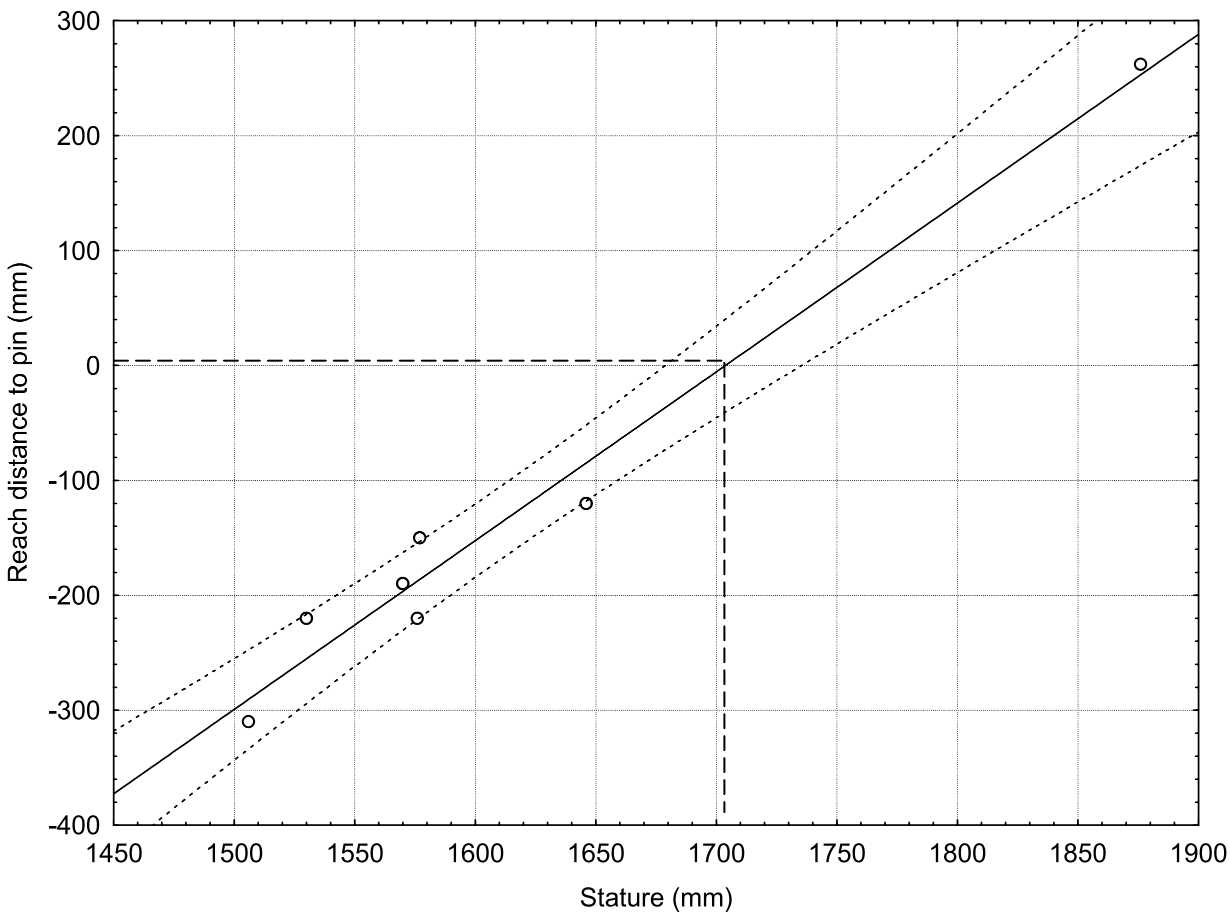


Figure 20 Stature versus reach distance to passenger service set-up pin.

Moving in tight spaces

The clearance available to individuals between the pallet and the fuselage are shown as a function of waist depth in Figure 21. As the clearance distance approaches zero, the chance of getting stuck in the “safety aisle” increases. The graph shows that the largest subject, with a waist depth of 330 mm, could comfortably cross the safety aisle. Extrapolation of the minimum clearance line to 383 mm, or the largest waist depth measured in the 1997 anthropometric survey, shows that even that individual would likely be able move across the safety aisle in summer clothing.

A precise screening limit cannot be established with the current data for at least two reasons. The first one is that the data are quite variable – due to the variability in shape of the participants presumably – and relatively sparse. The consequence of this is reflected the width of the 95% confidence limits (dotted lines) in Figure 21. The second reason is that winter clothing, which was not assessed in this study, could reduce the clearance by 10 to 20 mm and put some of the extremely large individuals at risk. Therefore, a precautionary waist depth limit of 380 mm or so should probably be implemented whose transgression would trigger a mobility test in winter clothing in a pallet-loaded CC-130 Hercules.

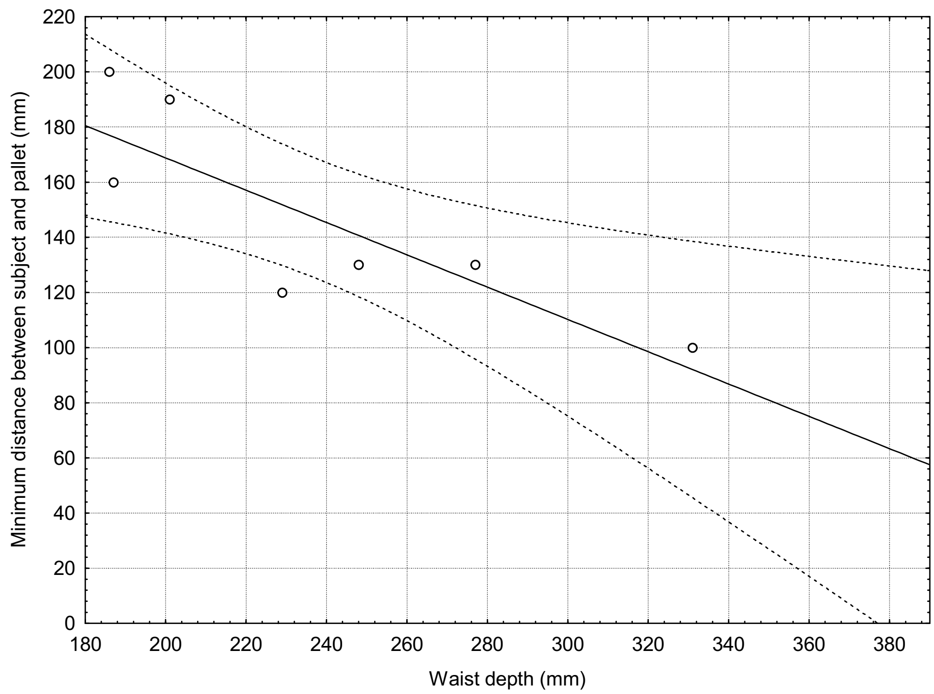


Figure 21. Minimum clearance between pallet and fuselage versus waist depth.

A step ladder is available to FEs to carry out tasks such as engine inspection and pre- and post-flight preparations. Rather than assessing participants, measurements were taken from the ladder steps to the engine's intake and exhaust. The data, listed in Table 12, indicate that the ladder allows short individuals to carry out the pre- and post-flight preparations given the fact that an extra rung is available (assuming bracing against the engine).

Table 12 Ladder engine inspection tasks

Description	Distance (mm)
Ladder height (from ground to 2nd rung from top)	2320
Ladder rung separation	300
From 2nd Rung to top of engine	1900
From 2nd rung to view of engine exhaust	1030
Outboard vs. inboard engine height differential	40

3.2.3 CC-150 Polaris

The results of the emergency kit reach task are listed in Table 13. The ability to remove the kit from the floor (bin-floor) or by using the seat arm as a boost (bin-seat) is listed in ascending order of stature to show the link between that variable and task performance. It is clear that short individuals will not be able to complete the task of removing the emergency kit from the overhead bin without the use of a boost, which means that a lower limit is required. Based on this task, a minimum of 1570 mm in stature would be required. This is consistent with the lower limit set by commercial airlines[4].

Table 13. Emergency kit reach

Subject	Stature (mm)	Bin-Floor	Bin-Seat
4	1506	fail	pass
2	1530	fail	pass
6	1570	pass	pass
1	1576	pass	pass
5	1577	pass	pass
7	1646	pass	pass

4 http://www.calmis.ca.gov/file/occguide/FLIGHTAT.HTM

4 Conclusions and recommendations

CH-149 Cormorant:

A lower limit of 1670 mm (or 5 feet 6 inches) appears warranted due to the requirement to reach the hoist halos with the right shoulder braced against the door opening. Due to the limited ceiling height inside the cargo hold, individuals taller than 1800 mm (5 feet 11 inches) will not be able to stand up straight and therefore need to carry out their duties in a hunched posture. This may be more than a nuisance in that poor posture could compound the difficulty of some of the heavy lifting and carrying tasks and thus increase the risk of musculo-skeletal injury.

Strength requirements, which were outside the scope of this study, are an important consideration in this job and one that would probably prove limiting for some. It is recommended that this situation be studied for health and safety reasons, with a view to developing a screening test that could be used to identify individuals requiring strength training.

CP-140 Aurora:

The preparation of the pannier hooks proved to be the most challenging for short individuals, requiring a minimum stature of about 1700 mm (5 feet 7 inches) to be able to perform the task unaided. With the use of a boost, such as the plastic milk crate commonly available and used to extend reach, individuals as short as 1517 mm (5 feet) or so should be able to perform this task, making the vast majority of the CF population eligible for this job from an anthropometric standpoint. However, as in the case of the CH-149 Cormorant, the strength requirements of this job were not addressed although they appear to be limiting for some. This issue may require further study from a health and safety standpoint.

CC-130 Hercules:

Operation of the parachute door is one of the critical aspects of the LM’s job and one that has an anthropometric as well as a biomechanical component. From the results of this study, the anthropometric component is not very limiting as the vast majority of males and females would be able to perform the kinematics of this task. Unfortunately, the biomechanical aspects, which appear to be more limiting, could not be included in this assessment. However, these aspects are sufficiently important to warrant further study. The introduction of a suitable strength test – if one doesn’t already exist – should be considered that could, if not screen out candidates, at least identify those requiring strength training.

Setting up of the passenger comfort services is an awkward task and proved to be a challenging one for short individuals. The stature required to perform this task successfully is about 1700 mm (5 feet 7 inches), which represents the 88^{th} percentile female and the 21^{st} percentile male. Unlike in the case of the CP-140 Aurora, where the task is performed on level ground where a milk crate or small ladder can be used, set-up of the passenger comfort services is performed in flight and from an angled platform. Unless an aid of some sort can be provided, the recommended minimum stature should be established at 1700 mm.

An anthropometric limitation was identified relative to the actuation of the bleed-air valve. However, this can easily be overcome by providing a longer extension rod. An extra 275 mm would accommodate the entire population.

Waist depth is a determinant of safety aisles clearance, but exact screening limits could not be established from the data collected. As a precaution, a waist depth limit of 380 mm or so should probably be implemented. The mobility of individuals beyond this value should be assessed in a pallet-loaded CC130 in winter clothing.

CC-150 Polaris:

A height restriction of 1570 mm (5 feet 2 inches) should be applied to flight attendants based on the ability to perform the emergency kit reach task. This value is entirely consistent with the lower limit set by commercial airlines[5].

Proposed occupation-specific height requirements:

The results of this study show that occupational-specific anthropometric requirements are indeed required - and would still be required if the minimum height standard of 1520 mm was still in place. While some of the limitations of the tasks assessed can be alleviated through the provision of simple aids, others cannot. Table 14 shows a list of limits that remain in spite of the option to provide aids. As shown, most of the limitations occur at the lower end of the spectrum, where minimum statures apply to all trades.

Upper-end limits were found for some tasks, but these had less to do with BFOR than with optimal working conditions, health and safety. For instance, although not impinging on the ability to perform the job and therefore not a BFOR, a suggested maximum for stature in the CH-149 Cormorant was provided that could be used to assign the tallest FEs to the CP-140 Aurora rather than the CH-149 Cormorant – choice permitting.

Table 14. Summary of restrictions by trade.

Trade	Aircraft	Limiting Task	Stature (mm)		Waist depth (mm)
			min	max	
Flight Engineer	CH-149 Cormorant	Hoists	1670	1766[6]	-
	CP-140 Aurora	Pannier	1517	-	-
Loadmaster	CC-130 Hercules	Facility preparation	1700	-	-
		Safety aisle clearance	-	-	380[7]
Flight attendants	CC-150 Polaris	Bin reach	1570	-	-

It is recommend that the information presented herein be reviewed by the appropriate technical authorities to establish the *Bona Fide* nature of the tasks identified as limiting, and then to obtain a consensus on the required screening limits and their implementation. Also, the strength requirements of the FE occupation should be studied further.

5 http://www.calmis.ca.gov/file/occguide/FLIGHTAT.HTM (accessed Apr 08)
6 Not a BFOR, optimal limit only
7 Individuals above this value should be tested for safety aisle clearance in winter clothing.

References

Chamberland, A., Carrier, R., Forest, F., & Hachez, G. (1998). *Anthropometric survey of the Land Forces (LF97)* (Contractor report No. 98-CR-15). Toronto, Ontario: Defence and Civil Institute of Environmental Medicine.

Department of Justice. Canadian Human Rights Act (R.S., 1985, c. H-6). *http://laws.justice.gc.ca/en/H-6/index.html?noCookie*. (accessed Apr 08)

Johnston, J. (2004). CF Enrolment Minimum Height Standard: email from Air Command Personnel Selection Officer, D Air PPD 2-4, dated 26 July 2004.

Olsen, J. K. (2002). CF enrolment minimum height standard - cancellation of existing policy (No. 5671-0 (DMHRR) dated 28 February 2002).

This page intentionally left blank.

Annex A Review of non-pilot occupation

CP-140 Aurora

General

The CP-140 Aurora crew is composed of 2 pilots, 1 flight engineer, 4 navigators, 3 Airborne Electronic Sensor Operators (AESOp) (crew size will vary depending on the mission).

Task descriptions

Flight Engineer

<u>Overhead reach, bomb bay</u>. The FEs need to load and unload the pannier into or from the bomb bay. When loading, the fuel tanks tend to be full and the aircraft sits low, making the pannier easier to load than with a light fuel load. Unloading is a more challenging task for shorter individuals since the aircraft sits higher by several centimetres. In that instance, even moderately tall personnel need to use some kind of boost (e.g., a milk crate, which is carried for this and other purposes) to make the job easier to do.	
<u>Refuelling:</u> refuelling is a two-handed operation that requires lifting of a large hose. However, the wing is fairly low even when the aircraft is empty.	

<u>Take-off and landings:</u> the FE needs to operate the throttles on take-off. This requires pushing the levers forward as the aircraft accelerates. The acceleration increases the difficulty of the task because the FE must resist being pushed back. The seat belt is on but is loosened to enable the reach. Fire suppression handles also need to be reached in case of emergency. Those are not difficult to reach.	 
<u>Tow bar and tool boxes:</u> The tow bar, which is quite heavy, needs to be lifted and moved to the aircraft. This activity requires strength has no associated anthropometric limitations. The tool boxes, which are on wheels, need to be loaded onto the aircraft. Those two tasks, as well as a multitude of others, require strength but are not very demanding anthropometrically.	 

AESOp

<u>Loading of ordnance:</u> the loading of ordnance can be done through the underbelly of the aircraft. The ordnance is pushed up through the general purpose chute and received inside the aircraft by a second crew member. This activity can be a concern if an individual is too short and cannot push the ordnance high enough to be picked from inside the aircraft. The consequence would be that the ordnance would have to be loaded by climbing the ladder and entering through the door, or designating a taller individual to perform that task. Once inside the aircraft, the ordnance is placed into a holding rack. The rack is not very high and does not appear to pose a problem. The sonobuoys can weigh up to ~40lbs but are easy to grasp and handle. This activity should not cause any problems for most of the male or female population.	 
<u>Replacing of electronic systems;</u> the electronics need replacing from time to time. The electronic racks can weigh up to ~70lbs, which may be too heavy for one person. Two people are needed to remove a rack and carry it down the boarding staircase. The position of the racks in the aircraft makes them easy to access and remove.	

Console operation: the consoles at the front of the cabin are simple and easily accessible. The chairs are adjustable and should accommodate most males and females.	
Radar transmitter: the radar transmitter weighs about 170lbs (80 kg) and requires two persons to carry into (and out of) the aircraft, via the ladders. This task requires a fair degree of strength and balance, but is not limited by the anthropometry of a person.	
Overhead grasp bar: walking from one end of the aircraft to another in turbulent air requires steadying. The aircraft has an overhead bar that is placed relatively high, and although it may not be accessible to everyone, shorter individuals can use other objects to stabilize themselves, such as walls, bulkheads etc.	

CH-149 Cormorant

General

The CH-149 Cormorant crew is composed of 2 pilots, 1 FE, 2 SAR techs.

Task descriptions

Flight Engineer (FE)

Reach from the door seat. The microphone switches are located overhead in a difficult-to-reach area. However, the switch is turned on once or twice (i.e., not very often) during flight and is more of an inconvenience than a critical operational or safety risk. It does not pose an anthropometric screening issue.	
There are other controls over the cargo door, but the ceiling is only about 6 feet, so the overhead reach is easy. It should be noted that due to the low ceiling, a large proportion of males need to adopt a hunched posture when standing or walking in the cabin when wearing their helmet.	

Hoisting. Hoisting is one of the most demanding aspects of the FE's job. The first picture demonstrates the technique used to bring someone aboard. The right hand operates the hoist with the remote and the left hand pulls the load. Strength and coordination are required to bring the load in while releasing the cable using the remote control.	
The second picture shows two SAR techs being hoisted on board. Their total weight is about 350 lbs, which is below average for operational hoists; loads can reach 600 lbs (the maximum rating of the hoist) when rescuing fishermen with waterlogged clothing. Even at 350 lbs, pulling the two SAR techs in with one arm required a significant amount of grip, upper body strength, and technique.	
Hoisting of the Stokes litter is shown in the third picture. This activity requires additional manoeuvring in order to keep the litter in a stable and suitable orientation.	

<u>Reaching of the outboard hoist</u>: The task of reaching the outboard hoist may seem easy when performed in a hangar, unexposed to the buffeting of the wind or rotor blades. However, under operational conditions, FEs must brace themselves against the side of the door with their right shoulder. The right hand keeps a grasp of the remote control while the left hand reaches for the halo.	
<u>Confined areas.</u> When landing in confined areas, FE need to scan the ground under the aircraft for obstacles that may pose a hazard to it or destabilize it. They do this by lying on their stomach over the edge of the door with their torso hanging out. They must be able to see where the wheels will contact the ground and watch for protrusions that could damage the underbelly of the aircraft.	
<u>Rotor blade covers</u>; The rotor blades may need to be covered to protect them from the elements (ice mainly). The cover is a long sheet of plastic fabric that needs to be slipped on. Metal rods are attached to the end to enable the slipping on. This task is somewhat dangerous, and would be even more so for short individuals. It is performed infrequently.	

CH-124 Sea King

General

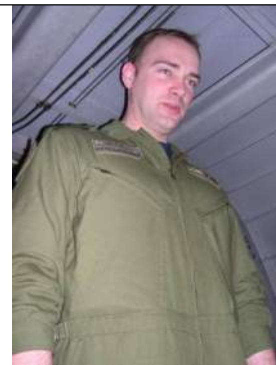
The AESOps and Tactical Communications officer (TACOs) work in a seated posture at the console, and in a standing posture at the back. The jobs at the back require strength in operating the hoist, casualty handing (in SAR missions), delivering ordnance (including sonobuoys and smoke), and deploying the 6-man raft (~80lbs).

The CH-124 Sea King crew is composed of 2 pilots, 1 TACO (Tactical Co-ordinator), 1 AESOp (Airborne Electronic Sensor Operator)

Task descriptions

AESOp

Leg clearance. The TACO and AESOps face the front during flight. There is a knee clearance issue for long-legged AESOps due to the proximity of the TACO's seat, but there is plenty of room for the TACO to move the knees to the side and mitigate the problem.	
When facing the console, both operators can move the seat vertically and horizontally (fore and aft), allowing a fair degree of adjustment. In that orientation, long-legged personnel will find the space a little tight. However, there is enough room to stretch the legs and mitigate the problem. A cursory assessment revealed that reaches to the console would not present a problem for short personnel. This was confirmed anecdotally as a 4 feet 11 inches AESOp is currently, or has recently been, operating the console. The CH-124 Sea King will soon be replaced by the Cyclone (CH-148).	

Head clearance. Larger individuals must bend their head or their trunk when walking in the cargo area.	
Reaching of hook: The hoist hook is easily accessible, even for a small individual	
Rescue harness. AESOps need to wear a rescue harness and bring people back on board. They would be helped in.	

<u>Escaping through hatches</u>. The escape window seems fairly large.	

CC-130 Hercules

General

LM do not physically load the aircraft, but are responsible for weight and balance of the cargo and fuel. They need to be qualified for aerial delivery of paratroops, and have to perform crew cabin duties. Loadmaster is a specialisation within Traffic Technician (TFC Techs) trade, which means that the pool of applicants for the LM trade is a subset of the Traffic Technicians, with all of the selection (self- and work-related) that this may imply, particularly with respect to strength, where there may be minimum requirements.

(FE are responsible for preparing the aircraft for flight, calculating power plant performance, weight and balance, take off and landing data, monitoring and controlling aircraft systems during flight, carrying out corrective actions during emergency situations or system malfunctions, completing post-flight inspections and advising the aircraft commander on technical matters. FEs must have aviation technologist (AVN Tech) experience before re-mustering.

The CC-130 Hercules crew is composed of 2 pilots, 1 navigator, 1 flight engineer, and 1 loadmaster, 2 SAR Technicians.

Task descriptions

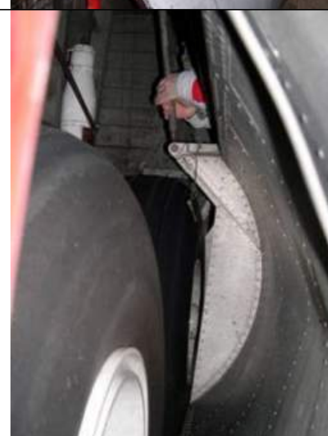
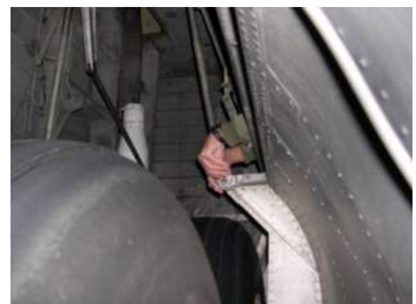
Loadmaster

<u>Rear door opening</u>. Personnel drops require the lifting of the rear door in flight. Because of the venturi effect, a certain amount of suction acts on the door and makes it more difficult to open during flight than when on the ground - where the testing occurs. Strength is needed to lift the heavy door, whether lifted with one hand (with the other on the side of the door to keep balance) or with two hands (a little riskier but also permitted). Overhead reach is required to lift the door all the way up, although a strong lift will generate enough momentum to carry the door to its limit without reaching that high. One of the shorter LM needs to use both hands to open the door and use a posture that increases the risk of falling out. LM wear a parachute in tactical operations; in SAR, the LM wear a harness attached to an anchor point.	

Lowering privacy screen for toilet. LM need to climb up the ramp and reach for the privacy screen mechanism. A LM of average height (5 feet 9 inches or 1.76 m) has to stretch to unlock the attachment (center anchor cable support). Putting the attachment back up is even more difficult than taking it down because it takes two hands. This task would be challenging for short individuals.	
Moving along "safety aisles." LM need to leave a 20 inch gap between the cargo and aircraft structure when the cargo is loaded - the gap can be as little as 14 in at the wheel wells. Individuals need to be thin enough to circulate through there with their clothing and equipment. Some people have been wedged-in – stuck – and had to be helped out. Not only can some people not do the job, but they could compromise the mission or be injured if this were to happen. With no passengers to carry, a load can have little or no clearance if it is less than 36 inches high. In those cases, crew can walk on tom. A minimum of 14 inches side clearance is required for loads more than 36 inches high.	
Rigging (the parachute line). This is done on the ground, and LM have access to a ladder.	
Escaping through hatches. The escape hatches seem large enough to accommodate all LM, especially given the fact that they must be able to travel through a 14 in safety aisle.	

Flight Engineers

A bleed-air (?) valve requires the help of an extension rod for actuation. Shorter individuals will find it impossible to reach.	
Inside the cockpit, the FE needs to be able to reach fuel valves. Due to the cockpit layout, they have to leave their seats, as shown in the photo. Consequently, even short individuals should be able to perform the task.	 
Reaching the canister can be done with the help of the bench (as shown) or using a ladder.	

Reach into wheel wells. FE need to reach inside the body of the aircraft to undo the mechanism that holds the undercarriage doors open so that they can be pushed up completely to enable them to inspect the wheels etc. The two openings are rather high considering that the arms must reach down to hold and unlock the retaining pin. Even taller individuals tend to use a block to ease this task.	 
FE needs to release the mechanism to allow panel to be raised. Left picture shows inability to access pin, and the need to reach down.	 
Strength is required to lift the panel and inspect the wheels. The ladder can be used to prop the panel open.	
FE need to climb ladder to inspect engine prior to flight and place protective covers afterwards in the engine intake and exhaust.	 

FE need to remove the heavy battery (~80 lbs?) when over-nighting in extreme cold areas. The battery itself is not difficult to reach, but its location, weight and size make it awkward to remove.		

CC-150 Polaris

General

The CC-150 Polaris crew is composed of 2 pilots, 1 or 2 loadmasters, and flight attendants

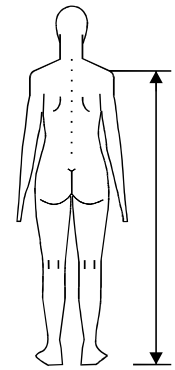
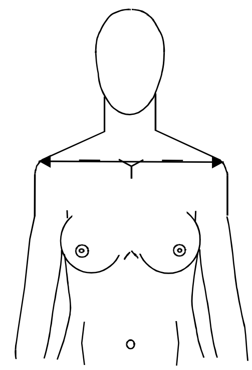
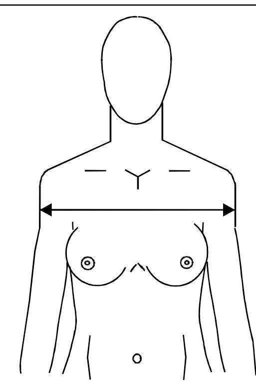
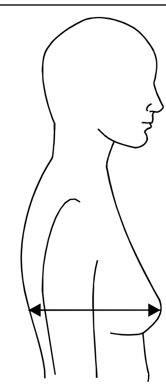
Task descriptions

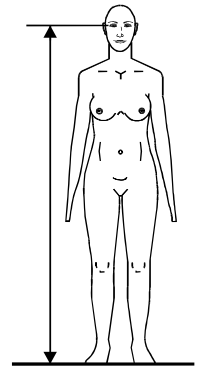
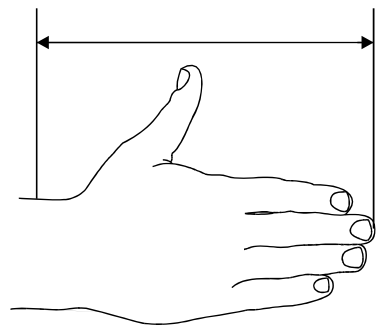
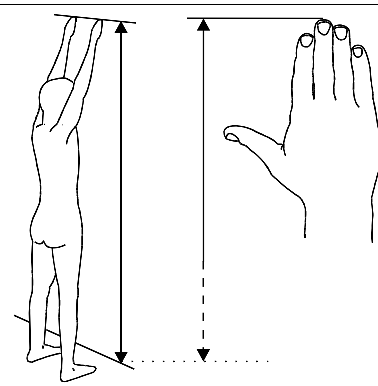
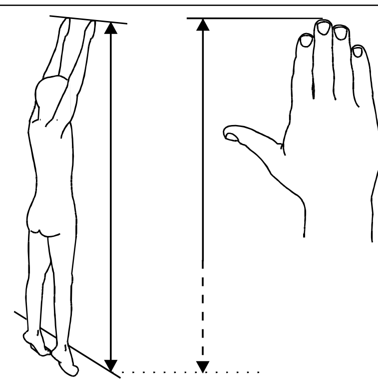
Loadmaster

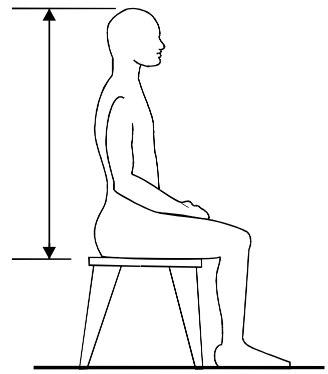
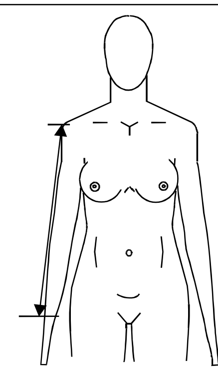
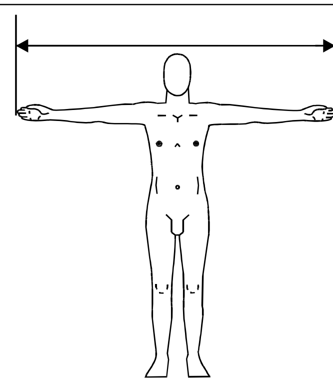
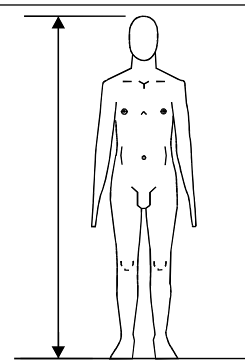
Cargo area sealing. Netting and canvas separators are installed by loadmasters. Use of a ladder makes this task accessible to all.	
Avionics bay. Crew need to access lower cargo bays through avionics bay hatch. The trap door is rather large, being about 17 inches x18 inches, and should not pose any problem.	

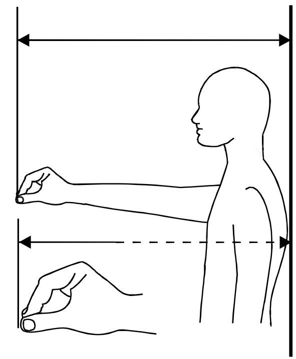
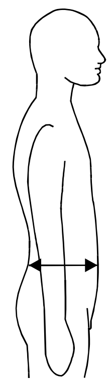
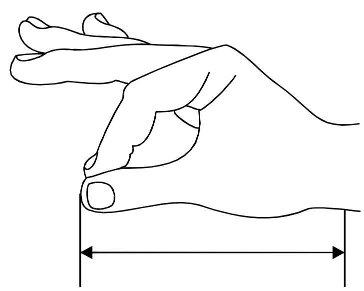
Emergency kit. Flight attendants may need to access a survival kit in case of emergency. The kit is in the aft-cabin in the centre overhead compartment. It is fairly heavy and somewhat difficult to reach for a small person. However, the arms of the seats are designed to act as foot supports to assist small individuals (passengers, flight attendants) in reaching the contents of the bin.	
Cargo Bay: 17 inches minimum clearance with double line of load. Due to a break in the curvature of the fuselage, this gap may be only 12-14 inches in mid section.	

Annex B Anthropometric measurement definitions

Acromial Height The vertical distance between a standing surface and the acromion landmark on the tip of the right shoulder is measured with an anthropometer. The subject stands erect looking straight ahead. The heels are together with the weight distributed equally on both feet. The shoulders and upper extremities are relaxed. The measurement is made at the maximum point of quiet respiration.	
Biacromial Breadth The distance between the right and left acromion landmarks at the tips of the shoulders is measured with a beam caliper. The subject sits erect. The shoulders and upper arms are relaxed and the forearms and hands are extended forward horizontally with the palms facing each other. The measurement is taken at the maximum point of quiet respiration.	
Bideltoid Breadth The maximum horizontal distance between the lateral margins of the upper arms on the deltoid muscles is measured with a beam caliper. The subject sits erect looking straight ahead. The shoulders and upper arms are relaxed and the forearms and hands are extended forward horizontally with the palms facing each other. The measurement is made at the maximum point of quiet respiration.	
Chest Depth The horizontal distance between the chest at the level of the right bust point on women or the nipple on men, and the back at the same level is measured with a beam caliper. The subject stands erect looking straight ahead. The shoulders and upper extremities are relaxed. The measurement is taken at the maximum point of quiet respiration.	

Eye Height The vertical distance between a standing surface and the outer comer of the right eye of a subject standing erect with the head in the Frankfort plane is calculated as follows: eye height sitting (154) + stature(2) - sitting height (4)	
Hand Length The length of the right hand between the stylion landmark on the wrist and the tip of the middle finger is measured with a Poech sliding caliper. The subject places the palm on a table, the fingers together, and the thumb abducted. The middle finger is parallel to the long axis of the forearm. The two distal phalanges of the fingers lie on a flat surface 8 mm. higher than the table.	
Overhead Fingertip Reach The vertical distance between a standing surface and the tip of the right middle finger when the arm is extended overhead is measured on a wall scale. The subject stands facing a wall-mounted scale with both arms extended overhead parallel to each other. The toes are 20 cm from the wall and the feet are about 10 cm apart. The palms of the hands rest on the scale. A block is placed against the tip of the finger to establish the measurement. The measurement is taken at the maximum point of quiet respiration.	
Overhead Fingertip Reach, Extended The vertical distance between a standing surface and the tip of the right middle finger when the arm is extended overhead as high as possible is measured on a wall scale. The subject stands on his/her toes facing a wall-mounted scale with both arms parallel and extended overhead as high as possible. The toes are 20 cm from the wall and the feet are about 10 cm apart. The palms of the hands rest on the scale. A block is placed against the tip of the finger to establish the measurement. The measurement is taken at the maximum point of quiet respiration.	

Sitting Height The vertical distance between a sitting surface and the top of the head is measured with an anthropometer. The subject sits erect with the head in the Frankfort plane. The shoulders and upper arms are relaxed and the forearms and hands are extended forward horizontally with the palms facing each other. The thighs are parallel and the knees are flexed 90 degrees with the feet in line with the thighs. The measurement is made at the maximum point of quiet respiration.	
Sleeve Outseam The straight-line distance between the acromion landmark on the tip of the right shoulder and the stylion landmark on the right wrist is measured with a tape. The subject stands erect with both arms straight at the sides and the palms facing forward.	
Span The distance between the tips of the middle fingers of the horizontally outstretched arms is measured on a wall chart. The subject stands erect with the back against a wall-mounted scale and the heels together. Both arms and hands are stretched horizontally against a back wall with the tip of the middle finger of one hand just touching a side wall. A block is placed at the tip of the middle finger of the other hand to establish the measurement on the scale. The measurement is taken at the maximum point of quiet respiration.	
Stature The vertical distance from a standing surface to the top of the head is measured with an anthropometer. The subject stands erect with the head in the Frankfort plane. The heels are together with the weight distributed equally on both feet. The shoulders and upper extremities are relaxed. The measurement is taken at the maximum point of quiet respiration.	

Thumb tip Reach The horizontal distance from a back wall to the tip of the right thumb is measured on a wall scale. The subject stands erect in a comer looking straight ahead with the feet together and the heels 20 cm from the back wall. The buttocks and shoulders are against the wall. The right arm and hand, palm down, are stretched forward horizontally along a scale on the side wall. The thumb continues the horizontal line of the arm and the index finger curves around to touch the pad at the end of the thumb. The subject's right shoulder is held against the rear wall.	
Waist depth The horizontal distance between the front and back of the waist at the level of the center of the navel (omphalion) is measured with a beam caliper. The subject stands erect looking straight ahead. The heels are together with the weight distributed equally on both feet. The measurement is taken at the maximum point of quiet respiration.	
Wrist-Thumb tip Length The horizontal distance between the stylion landmark on the right wrist and the tip of the right thumb is measured with a Poech caliper. The subject rests the little finger side of the hand on a flat surface. The thumb is held straight and in line with the long axis of the forearm. The thumb rests on the first knuckle of the curved index ringer.	

List of symbols/abbreviations/acronyms/initialisms

AESOp	Airborne Electronic Sensor Operators
AVN Techs	Aviation Technologists
BFOR	Bona Fide Occupational Requirement
CF	Canadian Forces
CFB	Canadian Forces Base
D Air PPD	Director Air Personnel Production and Development
DGMHRPP	Director General Military Human Resource Policy and Planning
DRDC	Defence R&D Canada
FE	Flight Engineers
LM	Load Masters
MOC	Military Occupation Code
NBC	Nuclear Biological Chemical
SAR	Search and Rescue
SKAD	Survival Kit Air Droppable
SME	Subject Matter Expert
TACO	Tactical Communications Officer
TFC Techs	Traffic Technicians
B	Regression coefficients in Tables 3 and 8
t-test	Student t-test statistic results in Tables 3 and 8
p-level	Probability levels in Tables 3 and 8

Distribution list

Document No.: DRDC TR 2008-015

LIST PART 1: Internal Distribution by Centre:

0 TOTAL LIST PART 1

LIST PART 2: External Distribution by DRDKIM

1 DAirPPD
1 DG Air Pers

2 TOTAL LIST PART 2

2 TOTAL COPIES REQUIRED

DOCUMENT CONTROL DATA

(Security classification of the title, body of abstract and indexing annotation must be entered when the overall document is classified)

1. ORIGINATOR (The name and address of the organization preparing the document, Organizations for whom the document was prepared, e.g. Centre sponsoring a contractor's document, or tasking agency, are entered in section 8.) Publishing: DRDC Toronto Performing: DRDC Toronto Monitoring: Contracting:	2. SECURITY CLASSIFICATION (Overall security classification of the document including special warning terms if applicable.) UNCLASSIFIED

3. TITLE (The complete document title as indicated on the title page. Its classification is indicated by the appropriate abbreviation (S, C, R, or U) in parenthesis at the end of the title)

Assessment of the anthropometric accommodation requirements of non−pilot aircrew in the CC−150 Polaris, CP−140 Aurora, CH−149 Cormorant and CC−130 Hercules aircraft. (U)
Exigences anthropométriques pour le personnel navigant dans le CC−150 Polaris, CP−140 Aurora, CH−149 Cormorant et CC−130 Hercules (U)

4. AUTHORS (First name, middle initial and last name. If military, show rank, e.g. Maj. John E. Doe.)

Pierre Meunier

5. DATE OF PUBLICATION (Month and year of publication of document.) May 2010	6a NO. OF PAGES (Total containing information, including Annexes, Appendices, etc.) 54	6b. NO. OF REFS (Total cited in document.) 4

7. DESCRIPTIVE NOTES (The category of the document, e.g. technical report, technical note or memorandum. If appropriate, enter the type of document, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.)

Technical Report

8. SPONSORING ACTIVITY (The names of the department project office or laboratory sponsoring the research and development − include address.)

Sponsoring:
Tasking:

9a. PROJECT OR GRANT NO. (If appropriate, the applicable research and development project or grant under which the document was written. Please specify whether project or grant.)	9b. CONTRACT NO. (If appropriate, the applicable number under which the document was written.)
10a. ORIGINATOR'S DOCUMENT NUMBER (The official document number by which the document is identified by the originating activity. This number must be unique to this document) DRDC Toronto TR 2008−015	10b. OTHER DOCUMENT NO(s). (Any other numbers under which may be assigned this document either by the originator or by the sponsor.)

11. DOCUMENT AVAILABILITY (Any limitations on the dissemination of the document, other than those imposed by security classification.)

Unlimited distribution

12. DOCUMENT ANNOUNCEMENT (Any limitation to the bibliographic announcement of this document. This will normally correspond to the Document Availability (11), However, when further distribution (beyond the audience specified in (11) is possible, a wider announcement audience may be selected.))

Unlimited announcement

DOCUMENT CONTROL DATA

(Security classification of the title, body of abstract and indexing annotation must be entered when the overall document is classified)

13. ABSTRACT (A brief and factual summary of the document. It may also appear elsewhere in the body of the document itself. It is highly desirable that the abstract of classified documents be unclassified. Each paragraph of the abstract shall begin with an indication of the security classification of the information in the paragraph (unless the document itself is unclassified) represented as (S), (C), (R), or (U). It is not necessary to include here abstracts in both official languages unless the text is bilingual.)

(U) In February 2002, the Director General Military Human Resource Policy and Planning (DGMHRPP) cancelled the Canadian Forces (CF) enrolment minimum height standard. It was concluded that “the Canadian Forces can no longer justify or defend this specific limitation (of 152 cm) on enrolment as a general standard,” although it had successfully defended it in the past. While the past arguments centered on the limited accommodation range of equipment and the liability that ill−fitting equipment had on the individual or a group (e.g.,, Nuclear Biological Chemical protection), these were no longer as valid today as they were back then; newer equipment “has a wider range of sizes, adjustable seating in most vehicles, etc..” The Director General advised that “should a minimum height requirement be required, it must be occupation specific and be reflected in the occupational specifications.” Going forward, the CF requires “well supported and a defensible argument(s) that establish restriction(s) as a Bona Fide Occupational Requirement (BFOR).” This report summarizes the work that was done to establish limits of accommodation for non−pilot aircrew, specifically Flight Engineers, Load Masters, Airborne Electronic Sensor Operators, and Flight Attendants. The results show that minimum heights are indeed required for these occupations.

(U) En février 2002, le directeur général – politiques et planification en ressources humaines militaires a aboli la norme de taille minimum des Forces Canadiennes. On a conclu que "les forces canadiennes ne peuvent plus justifier ou défendre cette limite spécifique (de 152 centimètres) comme norme générale,” bien qu'elle ait été défendue avec succès par le passé. Bien que les arguments du passé aient portés sur la gamme limitée d’accommodation de l'équipement et du danger que comporte le port d'équipement mal ajusté soit pour l'individu ou pour un groupe (par exemple protection NBC), ceux−ci ne sont plus aussi valables aujourd'hui; un plus large éventail de tailles est maintenant disponible, les sièges sont réglables dans la plupart des véhicules, etc. Le directeur général a indiqué que "si une grandeur minimum est nécessaire, elle doit être spécifique au métier et se refléter dans les caractéristiques professionnelles.” Dorénavant, les FC a besoin «d’arguments bien soutenus et défendables pour établir des exigences professionnelles justifiées.” Ce rapport résume le travail qui a été effectué pour établir des limites d’accommodation pour l'équipage aérien, en particulier les techniciens en systèmes aéronautique, arrimeurs, opérateurs de détecteurs électroniques aéroportés, et les agents de bord. Les résultats montrent qu’une stature minimale est effectivement requise pour ces professions.

14. KEYWORDS, DESCRIPTORS or IDENTIFIERS (Technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible keywords should be selected from a published thesaurus, e.g. Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus identified. If it is not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title.)

(U) anthropometry, workspace accommodation, aircrew selection

Defence R&D Canada

Canada's Leader in Defence
and National Security
Science and Technology

R & D pour la défense Canada

Chef de file au Canada en matière
de science et de technologie pour
la défense et la sécurité nationale

DEFENCE DÉFENSE

www.drdc-rddc.gc.ca